PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

YE et al

Group Art Unit: Not yet assigned

Application No.: Not yet assigned

Examiner: Not yet assigned

Filed: Concurrently herewith

Attorney Dkt. No.: 60279.00064

For: SINGLE-FIBER PROTECTION IN TELECOMMUNICATIONS NETWORKS

CLAIM FOR PRIORITY UNDER 35 USC § 119

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

October 16, 2003

Sir:

The benefit of the filing dates of the following prior foreign application(s) filed in the following foreign country(ies) is hereby requested for the above-identified patent application and the priority provided in 35 U.S.C. §119 is hereby claimed:

Patent Application No. 20031104 filed on July 25, 2003 **in** Finland

In support of this claim, certified copy(ies) of said original foreign application(s) is/are filed herewith.

It is requested that the file of this application be marked to indicate that the requirements of 35 U.S.C. §119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of these/this document(s).

Please charge any fee deficiency or credit any overpayment with respect to this paper to Counsel's Deposit Account No. 50-2222.

Respectfully submitted,

Douglas H. Goldhush
Registration No. 33,125

Customer No. 32294
SQUIRE, SANDERS & DEMPSEY LLP
14TH Floor
8000 Towers Crescent Drive
Tysons Corner, Virginia 22182-2700
Telephone: 703-720-7800
Fax: 703-720-7802

DHG:mm

Enclosure: Priority Document(s) (1)

PATENTTI- JA REKISTERIHALLITUS
NATIONAL BOARD OF PATENTS AND REGISTRATION

Helsinki 2.8.2003

ETUOIKEUSTODISTUS
PRIORITY DOCUMENT

Hakija Applicant	**Nokia Corporation** **Helsinki**
Patenttihakemus nro Patent application no	**20031104**
Tekemispäivä Filing date	**25.07.2003**
Kansainvälinen luokka International class	**H04B**

Keksinnön nimitys
Title of invention

"Single-fiber protection in telecommunications networks"
(Yksikuituinen suojaus tietoliikenneverkoissa)

Täten todistetaan, että oheiset asiakirjat ovat tarkkoja jäljennöksiä Patentti- ja rekisterihallitukselle alkuaan annetuista selityksestä, patenttivaatimuksista, tiivistelmästä ja piirustuksista.

This is to certify that the annexed documents are true copies of the description, claims, abstract and drawings originally filed with the Finnish Patent Office.

Pirjo Kaila
Tutkimussihteeri

Maksu	50 €
Fee	50 EUR

Maksu perustuu kauppa- ja teollisuusministeriön antamaan asetukseen 1027/2001 Patentti- ja rekisterihallituksen maksullisista suoritteista muutoksineen.

The fee is based on the Decree with amendments of the Ministry of Trade and Industry No. 1027/2001 concerning the chargeable services of the National Board of Patents and Registration of Finland.

Osoite: Arkadiankatu 6 A
P.O.Box 1160
FIN-00101 Helsinki, FINLAND
Puhelin: 09 6939 500
Telephone: + 358 9 6939 500
Telefax: 09 6939 5328
Telefax: + 358 9 6939 5328

12

SINGLE-FIBER PROTECTION IN TELECOMMUNICATIONS NETWORKS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention relates to passive optical networks, and in particular to protected passive optical networks.

DESCRIPTION OF THE RELATED ART

A Passive Optical Network (PON) is a high bandwidth point-to-multipoint optical fiber network. A PON typically consists of an Optical Line Terminal (OLT), which is connected to Optical Network Units (ONU) using only cables, optical splitters and other passive components (i.e. not transmitting signals using electricity). In a PON, signals are routed in such a way that all signals reach all interim transfer points of the PON.

The passive optical network technology has been considered a very promising solution into solving the last-mile problem. Logically a PON has e.g. a tree-like structure consisting of an optical line terminal, which is located e.g. in a central office (CO), and a plurality of optical network units, e.g. 64 ONUs. The PON technology eliminates the need for active equipment in the field between OLT and ONUs, which are commonly used in regular networks. A PON can provide, for example, a capacity of 1 Gbps. A single link failure may result in an intolerable traffic loss, which indirectly leads to revenue a loss. Thus, survivability becomes important especially when a PON is applied in a fiber-to-business and cellular-transport (CT) network environment.

Generally, there are two types of survivability architectures: a 1+1 architecture and a 1:1 architecture. The 1+1 architecture uses two overlaid PONs. The traffic is bridged into both a working PON and a protection PON. Upon receiving a signal in OLT, the traffic is selected based on signal quality. With this approach, fast protection can be achieved. However, in this architecture, no extra traffic can be supported. Compared with no protection case, it furthermore requires double bandwidth.

In the 1:1 architecture, under normal circumstances, the normal traffic is transmitted over the working PON. Once a failure occurs, the traffic is switched into the protection PON. The protection switching is slower relative to that of the 1+1 architecture. However, compared with the 1+1 architecture, it can either significantly reduce the spare capacity requirement or carry extra low priority traffic depending on the network design.

US 6,351,582 discloses one solution for optimizing passive optical networks. The passive optical network comprises a plurality of optical splitters/combiners, each comprising a first and second through ports and at least one drops port. The through ports of the plurality of splitters/combiners are concatenated to form a linear arrangement having two end through ports.

Figure 1 discloses one embodiment of the basic structure of a ring-protected passive optical network arrangement described in US 6,351,582. In this example, the PON comprises two interfaces IF1 and IF2 within an OLT unit 110, wherein IF1 operates in active mode and IF2 in standby mode. The PON comprises a plurality of passive nodes 10-13 and 15-18, which are preferably splitters/combiners and furthermore a plurality of ONUs 14 and 19. In Figure 1, splitters/combiners 10, 11, 15 and 16 are 1-by-2 or 2-by-1 splitters/combiners that couple optical power from and into the optical fiber.

One problem in prior-art solutions and also in the solution disclosed in Figure 1, is that an optical signal traversing through ring splitters/combiners 10 and 11 experience optical power losses at two different stages (ring splitters/combiners 10 and 11).

The prior-art passive optical networks involve further problems that have to be overcome. In an access network, the cost is a major concern since the number of users in the access network is much less than that in metro or backbone networks. Furthermore, there exists a problem of how to effectively provide protection against a single link failure in a PON based access network without significantly increasing the cost per user.

A further problem is how to implement fast fault detection in a PON. Yet a further problem is how to fast reroute the affected traffic from the working OLT to the protection OLT.

A further problem is how to solve the attenuation problem caused by protection elements.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between the interfaces and a plurality of passive nodes connected in the optical fiber between the interfaces, wherein in the passive nodes 2-by-2 splitters/combiners are used to couple optical power to and from the optical fiber at a predetermined split ratio.

In an embodiment, a plurality of split ratios is used among the passive nodes.

In a further embodiment, the split ratios are configured to provide variable symmetric split ratios among the passive nodes.

In a further embodiment, the single-fiber passive optical network further comprises a detector in the second interface for detecting the degradation in power level of optical signals received from the first interface via the optical fiber connection, and in response to detecting, switching on the second transmitter of the second interface in response to detecting the degradation in power level of the optical signals from the first interface with the detector.

According to a second aspect of the invention there is provided a method of detecting and recovering from a failure in a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between the interfaces, a plurality of passive nodes between the interfaces, a plurality of optical network units connected to the plurality of passive nodes, the method comprising the steps of sending optical signals from the first interface via the optical fiber connection to the second interface, detecting in the second interface the degradation in power level of the optical signals from the first interface, and in response to detection, switching on the second transmitter of the second interface.

In one embodiment, the method comprises the step of switching on the second transmitter of the second interface when the optical power of the optical signals received with the second receiver drops below a predetermined threshold value.

In a further embodiment, the method further comprises the step of switching off the second transmitter if the light level increases above the predetermined threshold value.

In a further embodiment, the method further comprises the step of keeping the second transmitter switched on if the light level increases above the predetermined threshold value.

In a further embodiment, the method further comprises the step of switching the second transmitter off and again on in order to verify that the cable is still broken.

In a further embodiment, the method further comprises the step of switching off the second transmitter if detecting abrupt changes in the amount of light after switching on the second transmitter.

In a further embodiment, the method further comprises the step of switching on the second transmitter again if the light level decreases below the predetermined threshold value.

In a further embodiment, after detecting in the second interface the degradation in the power level of the optical signals from the first interface, and wherein if the first and second interfaces are located in a single optical line terminal, the method further comprises the steps of starting in the second interface an auto-discovery process to register affected optical network units, and in response to the result of the auto-discovery process, updating an internal routing table of the optical line terminal and sending the affected downstream traffic of the affected optical network units using the second interface.

In a further embodiment, after detecting in the second interface the degradation in the power level of the optical signals from the first interface, and wherein if the first and second interfaces are located in different optical line terminals, the method further comprises the steps of starting in the second interface an auto-discovery process to register affected optical network units, establishing with the second interface a dedicated path between the interfaces, sending a notifying message from the second interface to the first interface, the notifying message comprising information about the affected optical network units, forwarding the downstream traffic of the affected optical network units from the first interface to the second interface via the dedicated path and forwarding the affected upstream traffic from the affected optical network units from the second interface to the first interface via the dedicated path.

In a further embodiment, the method further comprises the step of sending from the first interface to the second interface via the dedicated path which higher layer addresses are behind the affected optical network units.

In a further embodiment, when receiving an upstream packet from the second interface, the method further comprises the steps of checking whether a packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending the packet according to the routing table, and if the destination address is not found in the routing table, sending the packet from the second interface to the first interface via the dedicated path.

According to a third aspect of the invention there is provided a method of detecting and recovering from a failure in a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between the interfaces, a plurality of passive nodes between the interfaces, a plurality of optical network units connected to the plurality of passive nodes, the method comprising the steps of detecting in the first interface that signals are not received from at least one optical network unit, and in response to detection, switching on the transmitter of the second interface.

In one embodiment, the method further comprises the step of switching off the transmitter of the second interface if the first interface detects that the number of optical network units from which signals are not received increases.

In a further embodiment, if the first and second interfaces are located in a single optical line terminal, the method further comprises the steps of starting in the second interface an auto-discovery process to register affected optical network units, and in response to the result of the auto-discovery process, updating an internal routing table of the optical line terminal, and sending the affected downstream traffic of the affected optical network units using the second interface.

In a further embodiment, if the first and second interfaces are located in different optical line terminals, the method further comprises the steps of establishing with the first interface a dedicated path between the interfaces, sending from the first interface to the second interface a message ordering to switch on the second transmitter of the second interface, starting in the second interface an auto-discovery process to register affected optical network units, sending a notifying message from the second interface to the first interface, the notifying message comprising information about the affected optical network units, forwarding the affected downstream traffic of the affected optical network units from the first interface to the second interface via the dedicated path, and forwarding the upstream traffic from the affected optical network units from the second interface to the first interface via the dedicated path.

In a further embodiment, the method further comprises the step of sending from the first interface to the second interface via the dedicated path which higher layer addresses are behind the affected optical network units.

In a further embodiment, when receiving an upstream packet via the second interface, the method further comprises the steps of checking whether the packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending the packet according to the routing table, and if the destination address is not found in the routing table, sending the packet from the second interface to the first interface via the dedicated path.

According to a fourth aspect of the invention there is provided a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between the interfaces, a plurality of passive nodes between the interfaces, a plurality of optical network units connected to the plurality of passive nodes and a detector in the second interface for detecting the degradation in power level of optical signals received from the first interface via the optical fiber, and in response to detecting, the second interface is configured to switch on the second transmitter in response to detecting the degradation in power level of the optical signals from the first interface with the detector.

In one embodiment, the second interface is configured to switch on the second transmitter of the second interface when the optical power of optical signals received with the second receiver drops below a predetermined threshold value.

In a further embodiment, the second interface is configured to switch off the second transmitter if the light level increases above the predetermined threshold value.

In a further embodiment, the second interface is configured to keep the second transmitter switched on if the light level increases above the predetermined threshold value.

In a further embodiment, the second interface is configured to switch the second transmitter off and again on in order to verify that the cable is still broken.

In a further embodiment, the second interface is configured to switch off the second transmitter if detecting with the detector abrupt changes in the amount of light after switching on the second transmitter.

In a further embodiment, the second interface is configured to switch on the second transmitter again if the light level decreases below the predetermined threshold value.

In a further embodiment, if the first and second interfaces are located in a single optical line terminal, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units and updating means for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process.

In a further embodiment, if the first and second interfaces are located in different optical line terminals, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, the second interface comprises establishing means for establishing a dedicated path between the interfaces, the second interface comprises sending means for sending a notifying message to the first interface, the notifying message comprising information about the affected optical network units, the first interface comprises forwarding means for forwarding the downstream traffic of the affected optical network units to the second interface via the dedicated path, and the second interface comprises forwarding means for forwarding the affected upstream traffic from the affected optical network units to the first interface via the dedicated path.

In a further embodiment, the first interface further comprises sending means for sending to the second interface via the dedicated path which higher layer addresses are behind the affected optical network units.

In a further embodiment, the second interface comprises checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending means for sending the packet according to the routing table, and if the destination address is not found in the routing table, sending the packet from the second interface to the first interface via the dedicated path.

According to a fifth aspect of the invention there is provided a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between the interfaces, a plurality of passive nodes between the interfaces, a plurality of optical network units connected to the plurality of passive nodes, detecting means for detecting in the first interface that signals are not received from at least one optical network unit, and sending means for sending to the second interface a message to switch on the transmitter of the second interface.

In one embodiment, the second interface is configured to switch off the transmitter of the second interface if the first interface detects that the number of optical network units from which signals are not received increases.

In a further embodiment, if the first and second interfaces are located in a single optical line terminal, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, and updating means for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process.

In a further embodiment, if the first and second interfaces are located in different optical line terminals the first interface comprises establishing means for establishing a dedicated path between the interfaces, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, the second interface comprises sending means for sending a notifying message to the first interface, the notifying message comprising information about the affected optical network units, the first interface comprises forwarding means for forwarding the downstream traffic of the affected optical network units to the second interface via the dedicated path, and the second interface comprises forwarding means for forwarding the affected upstream traffic from the affected optical network units to the first interface via the dedicated path.

In a further embodiment, the first interface further comprises sending means for sending to the second interface via the dedicated path the higher layer addresses that are behind the affected optical network units.

In a further embodiment, the second interface comprises checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending means for sending the packet according to the routing table, and if the destination address is not found in the routing table, the sending means configured to send the packet from the second interface to the first interface via the dedicated path.

According to a sixth aspect of the invention there is provided an interface arrangement for a protected single-fiber passive optical network, the arrangement comprising a first interface comprising a first transmitter coupled to the fiber for transmitting optical signals on a first wavelength and a first receiver coupled to the fiber for receiving optical signals on a second wavelength, a second interface comprising a second transmitter coupled to the fiber for transmitting optical signals on a second wavelength and a second receiver coupled to the fiber for receiving optical signals on a first wavelength, detecting means for detecting that signals are not received from at least one optical network unit, and sending means for sending to the second interface a message to switch on the second transmitter of the second interface.

In one embodiment, the second interface is configured to switch off the transmitter of the second interface if the first interface detects that the number of optical network units from which signals are not received increases.

In a further embodiment, if the first and second interfaces are located in a single optical line terminal, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, and updating means for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process.

In a further embodiment, if the first and second interfaces are located in different optical line terminals the first interface comprises establishing means for establishing a dedicated path between the interfaces, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, the second interface comprises sending means for sending a notifying message to the first interface, the notifying message comprising information about the affected optical network units, the first interface comprises forwarding means for forwarding the downstream traffic of the affected optical network units to the second interface via the dedicated path, and the second interface comprises forwarding means for forwarding the affected upstream traffic from the affected optical network units to the first interface via the dedicated path.

In a further embodiment, the first interface further comprises sending means for sending to the second interface via the dedicated path the higher layer addresses that are behind the affected optical network units.

In a further embodiment, the second interface comprises means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending means for sending the packet according to the routing table, and if the destination address is not found in the routing table, said sending means are configured to send the packet from the second interface to the first interface via the dedicated path.

According to a seventh aspect of the invention there is provided an interface arrangement for a protected single-fiber passive optical network, the interface arrangement comprising a first interface comprising a first transmitter coupled to the fiber for transmitting optical signals on a first wavelength and a first receiver coupled to the fiber for receiving optical signals on a second wavelength, a second interface comprising a second transmitter coupled to the fiber for transmitting optical signals on a second wavelength and a second receiver coupled to the fiber for receiving optical signals on a first wavelength, a detector coupled to the fiber for detecting the degradation in power level of incoming optical signals of the first wavelength via the fiber, and in response to detecting, the second interface is configured to switch on the second transmitter in response to detecting the degradation in power level of the optical signals of the first wavelength via the fiber.

In one embodiment, the second interface is configured to switch on the second transmitter when the optical power of the received optical signals of the first wavelength via the fiber drops below a predetermined threshold value.

In a further embodiment, the second interface is configured to switch off the second transmitter if the light level increases above the predetermined threshold value.

In a further embodiment, the second interface is configured to keeping the second transmitter switched on if the light level increases above the predetermined threshold value.

In a further embodiment, the second interface is configured to switch the second transmitter off and again on in order to verify that the cable is still broken.

In a further embodiment, the second interface is configured to switch off the second transmitter if the detector detects abrupt changes in the amount of light after switching on the transmitter.

In a further embodiment, the second interface is configured to switch the second transmitter again on if the light level decreases below the predetermined threshold value.

In a further embodiment, if the first and second interfaces are located in a single optical line terminal, the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, and updating means for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process.

In a further embodiment, if the first and second interfaces are located in different optical line terminals the second interface comprises starting means for starting an auto-discovery process to register affected optical network units, the second interface comprises establishing means for establishing a dedicated path between the interfaces, the second interface comprises sending means for sending a notifying message to the first interface, the notifying message comprising information about the affected optical network units, the first interface comprises forwarding means for forwarding the downstream traffic of the affected optical network units to the second interface via the dedicated path, and the second interface comprises forwarding means for forwarding the affected upstream traffic from the affected optical network units to the first interface via the dedicated path.

In a further embodiment, the first interface further comprises sending means for sending to the second interface via the dedicated path which higher layer addresses are behind the affected optical network units.

In a further embodiment, the second interface comprises checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising the second interface, and if the destination address is found in the routing table, sending means for sending the packet according to the routing table, and if the destination address is not found in the routing table, said means for sending are configured to sendthe packet from the second interface to the first interface via the dedicated path.

The invention has several advantages over the prior-art solutions. The invention adopts a single fiber to provide protection against single link failure or single OLT failure. Furthermore, it provides a solution for implementing fast fault detection and fault isolation. Moreover, the invention describes a solution how to transfer affected routing information from working OLT to the protection OLT. More particularly, the invention discloses an efficient optical protection solution, which can be used together with a higher layer protection solution. Alternatively, the higher layer protetion solution can be used without the optical protection solution disclosed in the invention.

The solution described in the invention is more cost-effective compared with the existing approaches since only a single fiber is used. Furthermore, the solution described in the invention requires less optical components.

The solution described in the invention saves optical power otherwise lost because of ring protection by using 2-by-2 and 2-by-n splitters.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

Fig 1 is a block diagram illustrating a prior-art solution for passive optical networks,

Fig 2 is a flow diagram illustrating a ring-protected PON arrangement in accordance with the invention,

Fig 3 discloses a transceiver used in prior-art solutions,

Fig 4 is a transceiver that can be used in PON arrangements in accordance with the invention,

Fig 5 is another transceiver that can be used in PON arrangements in accordance with the invention,

Fig 6 illustrates a method in accordance with the invention,

Fig 7 is graphical illustration of power levels of optical signals in a fiber cable break situation in accordance with the invention,

Fig 8a is a block diagram illustrating the interface arrangement when the interfaces are colocated in a single optical line terminal in accordance with the invention,

Fig 8b is a block diagram illustrating the interface arrangement when the interfaces are located in different optical line terminals in accordance with the invention,

Fig 8c is a block diagram illustrating the interface arrangement when the interfaces are colocated in a single optical line terminal in accordance with the invention,

Fig 8d is a block diagram illustrating the interface arrangement when the interfaces are located in different optical line terminals in accordance with the invention,

Fig 9 illustrates an exemplary network topology in which the invention can be used in accordance with the invention,

Fig 10 illustrates an exemplary network topology in which the invention can be used in accordance with the invention,

Fig 11 illustrates an exemplary network topology in which the invention can be used in accordance with the invention, and

Fig 12 illustrates the concept of a variable symmetric split ratio in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 2 describes a ring-protected PON arrangement configured to serve a number of subscribers. This arrangement comprises an OLT 200 comprising two interfaces 217 and 218, each comprising a transceiver. Interface 217 is an active interface whereas interface 218 is a standby interface. The distribution network in this example comprises three 2-by-2 ring splitters/combiners 20, 26, 29 connected by fiber distribution lines 213-216 to form a ring between the two interfaces 217 and 218. Each ring splitter/combiner 20, 26, 29 is linked to a number of subscriber ONUs 25, 28, 212 via intermediate splitters/combiners 22, 23, 24, 27, 210, 211. The transmitters of OLT 200 are configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, the receiver of OLT 200 is configured to receive optical signals on a second wavelength (for example 1310 nm). In order to avoid interference, the transmitter of ONUs 25, 28, 212 are configured to transmit optical signals on the second wavelength. Correspondingly, the receivers of ONUs 25, 28, 212 are configured to receive optical signals on the first wavelength.

When optical signals are transmitted from OLT 200 to ONU 25, optical signals flow from the active interface 217 over fiber distribution line 213 to ring splitter/combiner 20. Ring splitter/combiner 20 is configured such that a predetermined amount of the optical power of optical signals received is conveyed via optical medium 214 to ring splitter/combiner 26 from which it is transferred via optical medium 215 to ring splitter/combiner 29 etc. The remaining portion of the optical signals received at ring splitter/combiner 20 is conveyed to the downstream ports of splitter/combiner 23 and 24. The light received by ONU 25 is conveyed via splitters/combiners 22, 24.

In the reverse direction, when optical signals are transmitted from ONU 25 to OLT 200, a transceiver at ONU 25 emits an optical signal, which is conveyed via splitters/combiners 24, 22 to ring splitter/combiner 20. Ring splitter/combiner 20 splits the optical signal according to the predetermined split ratio, and the optical signal is conveyed via optical medium 213 to the active interface 217 whilst the other portion of the optical signal is conveyed via optical medium 214 to ring splitter/combiner 26 and further via optical medium 215 to ring splitter/combiner 29 and again via optical medium 216 to the standby interface 218. In other words, ring splitters/combiners 20, 26, 29 will split optical signals from ONUs 25, 28, 212 into different direction of physical ring, and signals can reach both the active interface 217 and the standby interface 218. In case of one link failure, OLT 200 can still keep all ONUs connected.

As illustrated in Figure 2, there are both 1-by-4 splitters/combiners and 2-by-8 splitters/ combiners. The 2-by-8 splitters/combiners can be used to save the number of components without changing optical properties. Of course a single 1-by-4 splitter/ combiner may be used if there are less ONUs required to be fed by that particular splitter/combiner.

In one embodiment of Figure 2, for upstream access (i.e. for traffic from ONUs to the OLT), time division multiple access (TDMA) is used. That is, every ONU 25, 28, 212 can only access the upper link at the time slot that OLT 200 authorizes it via gate messages, and therefore, no simultaneous access is allowed.

For comparison purposes, Figure 3 discloses a transceiver used in prior-art solutions. In Figure 3, an OLT interface 30 includes a transmitter 32 and a receiver 31. Transmitter 32 is configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, receiver 31 is configured to receive optical signals on a second wavelength (for example 1310 nm). OLT 30 comprises typically also a duplex filter 33 for filtering wavelengths of 1310 nm to receiver 31.

Figure 4 discloses one embodiment of a transceiver that can be used in the invention. In Figure 4, an OLT interface 40 includes a transmitter 42 and a receiver 41. Transmitter 42 is configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, receiver 41 is configured to receive optical signals on a second wavelength (for example 1310 nm). OLT interface 40 includes typically also a duplex filter 43 for filtering wavelengths of 1310 nm to receiver 41. Furthermore, OLT interface 40 includes a 1490 nm detector 44 enabling optical protection switching. A splitter 45 is configured to split light to detector 44. Optical protection switching is described in more detail with Figures 6 and 7. In the arrangement of Figure 4, with the disclosed location of detector 44, one can take advantage of the existing duplex filter 43.

Figure 5 discloses another embodiment of a transceiver that can be used in the invention. In Figure 5, an OLT interface 50 includes a transmitter 52 and a receiver 51. Transmitter 52 is configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, receiver 51 is configured to receive optical signals on a second wavelength (for example 1310 nm). OLT interface 50 includes typically also a duplex filter 53 for filtering wavelengths of 1310 nm to receiver 51. Furthermore, OLT interface 50 includes a 1490 nm detector 44 enabling optical protection switching. Optical protection switching is described in more detail with Figures 6 and 7.

In this example detector 54 is not inside the transceiver but before it. If detector 54 is in a location disclosed in Figure 5, one can take advantage of standard transceiver components.

The arrangement of Figure 5 includes a 1-by-2 splitter 55 splitting optical power to detector 54. The splitting ratio is e.g. 90%/10%. A 1-by-2 splitter could be replaced by e.g. a wavelength sensitive splitter, which would drop a small fraction of 1490 nm light only. The optical signal to detector 54 is filtered with a filter 56. Filter 56 is e.g. a 1490 band pass filter or a 1310/1490 high pass filter.

Figures 6 and 7 describe how the optical protection switching works in accordance with the invention. In the method disclosed in Figure 6, optical signals are sent from a first interface of an OLT to a second interface of an OLT, as indicated in step 60.

The interfaces can be in the same optical line terminal, or alternatively, in different optical line terminals. As long as the second interface receives optical signals (of a certain wavelength, e.g. 1490 nm) from the first interface, it can be assumed that the optical connection between the interfaces is undamaged.

Therefore, when the second interface detects the degradation in power level of optical signals from the first interface, it switches on the transmitter and starts to transmit optical signals towards the first interface, as indicated in steps 61 and 62. Exemplary embodiments for implementing the detection mechanism are described in Figures 4 and 5. In brief, a detector is used to detect that optical signals transmitted by the first interface are not received any more.

Figure 7 graphically illustrates the optical protection switching in accordance with the invention. In the optical protection switching solution, a predetermined threshold value is used for determining whether the optical fiber cable between the interfaces described in Figure 8 is broken. The interfaces can be located either in the same OLT or in different OLTs. Normally (point 1), the received light power is above the threshold. The meaning of the threshold value is that if the power level of the optical signals received at a detector in the second interface (see Figures 4 and 5) drops below the threshold value (point 2), it can be assumed that the fiber cable between the two interfaces is broken.

In response to the power level drop of the received optical signals, the transmitter of the second interface is turned on (point 3). From Figure 7 it can be seen that the power level of the received optical signals at the second interface arises due to reflection of light it transmits but still stays below the threshold value.

When the fiber cable has been repaired, there is a sudden growth in the power level of received optical signals (point 4). Because the power level now exceeds the threshold value, it can be assumed that the fiber cable has been repaired. Therefore, the transmitter of the second interface can be turned off (point 5).

The reflection caused by a broken cable has to be considered in detecting cable repair. In a single fiber ring case there is usually still about -10 dB of the transmitted power left when light is received at the other end of a repaired fiber ring. This is much more than the about -20 … -30 dB that is normally received from a reflection that occurs where a cable is broken. Thus, in most cases it is possible to determine a threshold value above which it is assumed that the fiber has been repaired. However, sometimes the reflected light can be larger than a useful value of a threshold that is used for protection switching.

The description disclosed in Figures 6 and 7 depicts a solution wherein a simple threshold value can be set to the detector. As mentioned above, there might arise situations, in which the threshold value is exceeded when the transmitter of the second interface is turned on even if the fiber cable is still broken. Therefore, this might lead to situations in which the transmitter of the second interface is turned off (because the threshold value is exceeded) although the fiber cable is still broken.

The invention further describes an improved solution that avoids the aforementioned problem. After switching on the second interface (protection interface), it is possible to measure how much light transmitted by the second interface is reflected back. The reflected level might be higher than the threshold value for assuming cable break, which could trick the second interface to believe that cable has been repaired. However, because it is known that the cable is broken (this can be checked by quickly turning the transmitter off and on again) and all light is reflected light, the second interface will remain turned on. As long as there are no abrupt changes in the amount of light after the second interface had been turned on, the second interface knows that the fiber cable has not been repaired.

If the power level, however, then changes in some way or another, the second interface may assume that the fiber cable has now been repaired, and therefore it can turn off the transmitter. If at this point power level of the received optical signals decreases below the original threshold value, meaning that the fiber cable is actually still broken, the second interface switches the transmitter quickly back on. This could happen in such a short time that all registered ONUs communicating through the second interface would remain registered.

The above-mentioned approach depends on optical layer detection. However, there is also a higher layer mechanism for detection a fiber cut and enabling the second interface. If the first interface does not receive signals from one or more ONUs, it considers that these ONUs are lost. The first interface can take actions based on whether it has PON physical topology information. If the first interface (node) is aware of the physical topology information based on the lost ONUs and physical topology information, the first interface can diagnose whether the failure is related to a fiber cut. If all the lost ONUs are behind a specific splitter on the fiber ring, it is considered that the fiber cut occurs after that splitter. Then the first interface enables the said second interface.

If physical topology information is not available, and when the first interface finds out that it has lost some ONUs, since it cannot figure out where the fault may occur, it will notify the second interface to enable the transmission. If the first and second interfaces are colocated in the same OLT, the enabling of the second interface is simple to implement. If, however, the interfaces are in different OLTs, in most situations there must be provided a dedicated connection between the interfaces in order to transmit the notification.

When both interfaces work simultaneously, it is possible to find out more of the type of failure. If ONUs lost from the first interface register to the second interface, the failure is a cable break in the fiber ring. If, on the other hand, the failure is somewhere else and the fiber ring was not broken, turning the second interface on will cause interference and subsequent loss of even more ONUs. In this case either the first interface or the second interface disables the second interface quickly. The approach takes only 1 to 2 ms to detect the fiber cut failure along the ring. To avoid frequent switches of the second interface due to other failures, such as an ONU failure or the fiber cut from a splitter to an ONU, the operator can set a threshold for the number of the lost ONUs. Therefore, only when the number of lost ONUs is more than a set threshold, the first interface will notify the second interface and enable transmission.

After a proper diagnosis of the fiber failure and enabling the second interface, an auto-discovery mechanism is performed in the second interface to synchronize ONUs with the second interface and measure the round trip delay between the second interface and its attached ONUs. Then the second interface will conduct round trip delay compensation and can start to send/receive traffic properly.

Figures 8a and 8b illustrate embodiments for interface arrangements of a passive optical network with the optical layer failure detection approach in accordance with the invention. The arrangements of Figures 8a and 8b enable optical protection switching which was described in more detail in Figures 6 and 7.

The first interface 86 of an OLT includes a transceiver 87 comprising a transmitter 890 and a receiver 88. Transmitter 890 is configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, receiver 88 is configured to receive optical signals on a second wavelength (for example 1310 nm). The first interface 86 of the OLT includes also a duplex filter 89 for filtering wavelengths of 1310 nm to receiver 88.

The second interface 80 of an OLT comprises a transceiver 81 comprising a transmitter 85 and a receiver 82. Transmitter 85 is configured to transmit optical signals on a first wavelength (for example 1490 nm). Correspondingly, receiver 82 is configured to receive optical signals on a second wavelength (for example 1310 nm). The second interface 80 of the OLT comprises also a duplex filter 83 for filtering wavelengths of 1310 nm to receiver 82. Furthermore, the second interface 80 comprises a 1490 nm detector 84 enabling optical protection switching. A splitter 893 is configured to split light to detector 84. Alternatively, detector 84 can be before transceiver 81 instead of being inside transceiver 81.

The arrangements of Figures 8a and 8b comprise also an optical medium 892 between the two interfaces 80, 86.

The difference between Figures 8a and 8b is that in Figure 8a interfaces 80, 86 are colocated at the same OLT (router), as shown in Figure 9, and in

Figure 8b interfaces 80, 86 are located at different OLTs (routers), as shown in Figures 10 and 11. The routers link a PON to an external network. The interfaces consist of a physical protocol layer, as well as higher layer or layers. Thus, routers represent here equipment having higher protocol layer or layers. Typical protocol layers are Ethernet, ATM (asynchronous transfer mode), or IP (Internet Protocol) layer or a combination of them. The following describes how higher layer operation may be enhanced by signaling between routers to ensure fast protection switching.

For the colocation case (Figure 8a), the node where interfaces 80 and 86 are located controls directly both interfaces. When a fiber cable break occurs, after detecting and diagnosing which the affected ONUs are, an OLT 91 in Figure 9 updates its internal routing table without advertising a PON failure to the rest of the routers in an external network, thus keeping protection switching local and quick. The traffic destined/originated to the affected ONUs will be sent/received through interface 80 instead of interface 86.

In the non-colocation case (Figure 8b) interfaces 86 and 80 are in separate nodes, which are able to communicate which each other through a dedicated path 891. If a fiber cable break occurs in the PON, the traffic going to the affected ONUs (ONUs that cannot be reached by interface 86) has to be rerouted to interface 80. In the case of an optical detection of a failure, as interface 80 detects a cable break optically using detector 84 it activates its transmitter 85, and starts an auto-discovery process to register the affected ONUs. At the same time, interface 80 sends a path establishment request to interface 86, and interface 86 replies with PATH-ACK. If interface 80 receives the PATH-ACK, the path is setup. Next, interface 80 will send notification message with the affected ONUs' information along the established path 891 to interface 86. The path establishment described above can be achieved by using a signaling protocol, for example, an extension of IETF (Internet Engineering Task Force) developed RSVP (Resource Reservation Set-up Protocol) or CR-LDP (Constraint-based Routing-Label Distribution Protocol) can be used to carry the needed information. The path can be used to exchange information and payload between the two routers without affecting packet forwarding in the rest of the external network. Thus, quick protection actions and rerouting of packets between the two routers can be accomplished.

After that interface 86 is notified of the failure and the affected ONUs so that interface 86 is able to stop sending traffic to the affected ONUs.

In the case optical detection is not used, the detection of a failure relies on the ability of interface 86 to recognize at higher layer that ONUs have been lost from the PON, as described earlier. Thus, the path initialization described above is initiated in interface 86 instead of interface 80.

Interface 86 notifies the router that it is attached to, to forward the affected downstream traffic to interface 80 using dedicated path 891. Interface 80 cannot simply forward all of its received upstream traffic to interface 86. Otherwise, a loop may occur. Figure 10 describes a probable implementation of non-colocation case. There, an interface 103 corresponds to interface 86 in Figure 8b and an interface 104 corresponds to interface 80 in Figure 8b. When a router 102 receives upstream traffic from a PON, and if it sends all packets to router 101, then router 101 processes these packets as they were originated from itself, some packets may travel through router 102 to their destinations, thus the loop occurs. To solve this problem, when an upstream packet arrives in router 102, router 102 checks the IP packet's destination address from its routing table, and if packet's address is in the routing table, router 102 sends the packet according to routing table. Otherwise, router 102 simply sends the packet to router 101 via the established dedicated path between router 101 and 102. The advantage for this approach is to keep the routing tables of the external network unchanged. When protection actions are complete, routers 101 and 102 may advertise the new stabilized topology to external network. Thus, the dedicated path between routers 101 and 102, otherwise consuming possibly excess bandwidth, is freed from payload traffic. In Figure 8a, in terms of Figure 9 OLT 91 updates its internal routing table, the traffic destined/originated to the affected ONUs will be sent/received through interface 93 instead of interface 92.

For achieving the aforementioned functionality for a colocation situation with optical detection illustrated in Figure 8a, interface 80 comprises starting means SM1 for starting an auto-discovery process to register affected optical network units and updating means UP for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process.

For achieving the aforementioned functionality for a non-colocation situation with optical detection illustrated in Figure 8b, interface 80 comprises starting means SM1 for starting an auto-discovery process to register affected optical network units, establishing means EM for establishing the dedicated path 891 between interfaces 80, 86, sending means SM2 for sending a notifying message to interface 86, the notifying message comprising information about the affected optical network units, and forwarding means FW2 for forwarding the affected upstream traffic from the affected optical network units to interface 86 via dedicated path 891. Interface 86 comprises forwarding means FW 1 for forwarding the downstream traffic of the affected optical network units to interface 80 via a dedicated path 891.

Furthermore, interface 86 may comprise sending means SM3 for sending to interface 80 via dedicated path 891 the higher layer addresses that are behind the affected optical network units. Moreover, Interface 80 may comprise checking means CM for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising interface 80 and sending means SM4 for sending the packet according to the routing table, and if the destination address is not found in the routing table, sending means configured to send the packet from interface 80 to interface 86 via dedicated path 891.

For achieving the aforementioned functionality for a colocation situation with only higher layer failure detection illustrated in Figure 8c, interface 80 comprises starting means SM1 for starting an auto-discovery process to register affected optical network units and updating means UP for updating an internal routing table of the optical line terminal in response to the result of the auto-discovery process. Correspondingly, interface 86 comprises detecting means DET for detecting in that signals are not received from at least one optical network unit and sending means SM5 for sending to interface 80 a message to switch on the transmitter of interface 80.

For achieving the aforementioned functionality for a non-colocation situation with only only higher layer failure detection illustrated in Figure 8d, interface 80 comprises starting means SM1 for starting an auto-discovery process to register affected optical network units, sending means SM2 for sending a notifying message to interface 86, the notifying message comprising information about the affected optical network units, and forwarding means FW2 for forwarding the affected upstream traffic from the affected optical network units to interface 86 via dedicated path 891. Interface 86 comprises forwarding means FW 1 for forwarding the downstream traffic of the affected optical network units to interface 80 via dedicated path 891. Furthermore, interface 80 comprises interface 80 may comprise checking means CM for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising interface 80 and sending means SM4 for sending the packet according to the routing table, and if the destination address is not found in the routing table, sending means SM4 configured to send the packet from interface 80 to interface 86 via dedicated path 891.

Correspondingly, interface 86 comprises detecting means DET for detecting that signals are not received from at least one optical network unit and sending means SM5 for sending to interface 80 a message to switch on the transmitter of interface 80. Furthermore, interface 86 comprises forwarding means FW1 for forwarding the downstream traffic of the affected optical network units to interface 80 via dedicated path 891, sending means SM3 for sending to interface 80 via dedicated path 891 which higher layer addresses are behind the affected optical network units, and establishing means EM for establishing the dedicated path 891 between interfaces 80,86.

The aforementioned means may be implemented with hardware and/or software solutions known to a man skilled in the art, and therefore they are not described in more detail.

Figures 9 - 11 describe exemplary passive optical network topologies in which the invention can be used. Each of the topologies is greatly simplified and is presented only for demonstrative purposes. Figure 9 describes a loop topology for passive optical networks 90 in which both interfaces 92, 93 are in the same OLT 91. Several ONUs 94 are connected to the optical medium 95. Figure 10 describes a U chain topology for passive optical networks 100 in which the first interface 103 is in OLT 101 and the second interface 104 in OLT 102. Several ONUs 105 are connected to the optical medium 106. Figure 11 describes a loop topology for passive optical networks 120 in which the first interface 123 is in OLT 121 and the second interface 124 in OLT 122. Several ONUs 125 are connected to the optical medium 126.

Optical protection switching provides a fast detection solution for detecting cable breaks. It was described earlier that there exists a connection between the two interfaces (other than the optical medium between the interfaces). This enables fast rerouting of information of affected ONUs. However, it must be noted that the Internet Protocol (IP) layer is able to learn the altered network topology without direct signaling between the OLTs. However, this learning may take many seconds and packets are lost. This solution is therefore more ineffective than the solution described in the invention.

Thus, optical protection switching in accordance with the invention can be used in Figures 9 and 10, whereas in Figure 11 it is more difficult because the connection between routers 121 and 122 (other than optical medium 126) may involve multiple hops and domains. Therefore, a dedicated path between the routers is more difficult to set up, has larger latency, and may be clearly more bandwidth constrained than a direct or a few-hop connection. If failure detection is based on the detector in the second interface, for example in router 102, the second interface will activate itself. After some time, routing information will be updated using normal IP routing protocols.

If, on the other hand, failure detection is based on the first interface noticing a loss of ONUs at higher layer, now in router 101, router 101 must send a notification message to router 102 so that the second interface can activate itself. Because in this detection scheme there is a significant probability that the second interface must be deactivated immediately upon activation, a special care should be taken that messages between the two routers propagate as quickly as the circumstances allow.

Figure 12 illustrates the concept of a variable symmetric split ratio solution. The concept is illustrated in a ring-protected passive optical network comprising an optical line terminal (OLT) 130 comprising an active interface 131 and a backup interface 132. The PON comprises also four ring splitters/combiners 132, 133, 134, 135. The aforementioned elements are connected to each other as disclosed in Figure 12 via an optical medium 136. The two interfaces can locate also in different OLTs (not presented in Figure 12).

Normally one of the two interfaces 131, 132 in OLT 130 is active. The interface sends light at one wavelength, normally 1490 nm, and receives at another, normally 1310 nm. Ring splitters/combiners 132, 133, 134, 135 are star points, which divide optical signals to ONUs (not presented in Figure 12).

In a bi-directional ring (such as a ring-protected passive optical network) the first drop node in one direction is the last node in the other direction. If the method applicable to a unidirectional fiber was be used here (i.e. dropping only a small fraction of optical power from the ring in drop nodes near the origin and larger fraction in subsequent drop nodes), the first drop in the reverse direction would tap more power than necessary and the last nodes would not receive enough power. Following from that, tapping equal fraction of light at each drop node is a suitable solution. Normally, the same splitting ratio is used to drop power from the ring in ring splitter/combiners 132, 133, 134, 135. However, the number of ONUs may be increased when a variable symmetric split ratio scheme is used in which a larger proportion of light is dropped at ring splitters/combiners 132, 133, 134, 135, which are near to OLT 130, and less power is dropped at ring splitters/combiners 132, 133, 134, 135, which are midway through the ring.

The following table shows how the number of ONUs can be increased by the variable symmetric split ratio in a system where a power budget of 24 dB is assumed.

Constant split ratio		Variable symmetric split ratio	
8 per drop, 3 drops		8 per drop, 4 drops	
Drop %	dB	Drop %	dB
20 %	-19,4	30 %	-17,6
20 %	-21,3	20 %	-22,0
20 %	-23,2	20 %	-23,9
20 %	-25,1	30 %	-24,0

A single fiber ring with 2 km distance between each ring splitter/combiner 132, 133, 134, 135 is used as the topology. Each ring splitter/combiner 132, 133, 134, 135 distributes signal to eight ONUs. The dB values indicate received optical power at OLT 130 relative to the transmitted power at ONUs (upstream direction used in the calculation is more critical in terms of power budget because attenuation is larger at wavelengths usually used by ONUs). In a constant split ratio, a 20 % drop ratio in every ring splitter/combiner 132, 133, 134, 135 gives best performance for a three-node system assuming a stock of splitters with 10% step between each model. However, at a 24 dB power budget there is not enough power at the fourth node. Thus, three nodes is the maximum number of nodes. If on the other hand, a variable symmetric split ratio is used, the fourth node will just fit into the power budget.

It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within the scope of the claims.

WE CLAIM:

1. A single-fiber passive optical network comprising:

a first interface comprising a first transmitter and a first receiver;

a second interface comprising a second transmitter and a second receiver;

an optical fiber connection between said interfaces; and

a plurality of passive nodes connected in said optical fiber between said interfaces, wherein in said passive nodes 2-by-2 splitters/combiners are used to couple optical power from and into said optical fiber at a predetermined split ratio.

2. The single-fiber passive optical network according to claim 1, wherein a plurality of split ratios is used among said passive nodes.

3. The single-fiber passive optical network according to claim 2, wherein said split ratios are configured to provide a variable symmetric split ratios among said passive nodes.

4. The single-fiber passive optical network according to claim 1, wherein the single-fiber passive optical network further comprises:

a detector in said second interface for detecting the degradation in power level of optical signals received from said first interface via said optical fiber connection; and in response to detecting, switching on said second transmitter of said second interface in response to detecting said degradation in power level of said optical signals from said first interface with said detector.

5. A method of detecting and recovering a failure in a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second

receiver, an optical fiber connection between said interfaces, a plurality of passive nodes between said interfaces, a plurality of optical network units connected to said plurality of passive nodes, the method comprising the steps of:

sending optical signals from said first interface via said optical fiber connection to said second interface;

detecting in said second interface the degradation in power level of said optical signals from said first interface; and in response to detection,

switching on said transmitter of said second interface.

6. The method according to claim 5, wherein the method comprises the step of:

switching on said second transmitter of said second interface when the optical power of said optical signals received with said second receiver drops below a predetermined threshold value.

7. The method according to claim 6, wherein the method further comprises the step of:

switching off said second transmitter if the light level increases above said predetermined threshold value.

8. The method according to claim 6, wherein the method further comprises the step of:

keeping said second transmitter switched on if the light level increases above said predetermined threshold value.

9. The method according to claim 8, wherein the method further comprises the step of:

switching said second transmitter off and again on in order to verify that the cable is still broken.

10. The method according to claim 6, wherein the method further comprises the step of:

switching off said second transmitter if detecting abrupt changes in the amount of light after switching on said second transmitter.

11. The method according to claim 10, wherein the method further comprises the step of:

switching on said second transmitter again if the light level decreases below said predetermined threshold value.

12. The method according to claim 5, wherein after detecting in said second interface the degradation in the power level of said optical signals from said first interface, and wherein if said first and second interfaces are located in a single optical line terminal, the method further comprises the steps of:

starting in said second interface an auto-discovery process to register affected optical network units; and in response to the result of said auto-discovery process,

updating an internal routing table of said optical line terminal; and

sending the affected downstream traffic of said affected optical network units using said second interface.

13. The method according to claim 5, wherein after detecting in said second interface the degradation in the power level of said optical signals from said first interface, and wherein if said first and second interfaces are located in different optical line terminals, the method further comprises the steps of:

starting in said second interface an auto-discovery process to register affected optical network units;

establishing with said second interface a dedicated path between said interfaces;

sending a notifying message from said second interface to said first interface, said notifying message comprising information about said affected optical network units;

forwarding the downstream traffic of said affected optical network units from said first interface to said second interface via said dedicated path; and

forwarding the affected upstream traffic from said affected optical network units from said second interface to said first interface via said dedicated path.

14. The method according to claim 13, wherein the method further comprises the step of:

sending from said first interface to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

15. The method according to claim 14, wherein when receiving an upstream packet via said second interface, the method further comprises the steps of:

checking whether said packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending said packet according to said routing table, and if said destination address is not found in said routing table,

sending said packet from said second interface to said first interface via said dedicated path.

16. A method of detecting and recovering from a failure in a protected single-fiber passive optical network comprising a first interface comprising a first transmitter and a first receiver, a second interface comprising a second transmitter and a second receiver, an optical fiber connection between said interfaces, a plurality of passive nodes between said interfaces, a plurality of optical network units connected to said plurality of passive nodes, the method comprising the steps of:

detecting in said first interface that signals are not received from at least one optical network unit; and in response to detection,

switching on said transmitter of said second interface.

17. The method according to claim 16, wherein the method further comprises the step of:

switching off said transmitter of said second interface if said first interface detects that the number of optical network units from which signals are not received increases.

18. The method according to claim 16, wherein if said first and second interfaces are located in a single optical line terminal, the method further comprises the steps of:

starting in said second interface an auto-discovery process to register affected optical network units; and in response to the result of said auto-discovery process,

updating an internal routing table of said optical line terminal; and

sending the affected downstream traffic of said affected optical network units using said second interface.

19. The method according to claim 16, wherein if said first and second interfaces are located in different optical line terminals, the method further comprises the steps of:

establishing with said first interface a dedicated path between said interfaces;

sending from said first interface to said second interface a message ordering to switch on said second transmitter of said second interface;

starting in said second interface an auto-discovery process to register affected optical network units;

sending a notifying message from said second interface to said first interface, said notifying message comprising information about said affected optical network units;

forwarding the affected downstream traffic of said affected optical network units from said first interface to said second interface via said dedicated path; and

forwarding the upstream traffic from said affected optical network units from said second interface to said first interface via said dedicated path.

20. The method according to claim 19, wherein the method further comprises the step of:

sending from said first interface to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

21. The method according to claim 20, wherein when receiving an upstream packet via said second interface, the method further comprises the steps of:

checking whether said packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending said packet according to said routing table, and if said destination address is not found in said routing table,

sending said packet from said second interface to said first interface via said dedicated path.

22. A protected single-fiber passive optical network comprising:

a first interface comprising a first transmitter and a first receiver;

a second interface comprising a second transmitter and a second receiver;

an optical fiber connection between said interfaces;

a plurality of passive nodes between said interfaces;

a plurality of optical network units connected to said plurality of passive nodes;

a detector in said second interface for detecting the degradation in power level of optical signals received from said first interface via said optical fiber; and in response to detecting, said second interface is configured to switch on said second transmitter in response to detecting said degradation in power level of said optical signals from said first interface with said detector.

23. The protected single-fiber passive optical network according to claim 22, wherein said second interface is configured to switch on said second transmitter of said second interface when the optical power of optical signals received with said second receiver drops below a predetermined threshold value.

24. The protected single-fiber passive optical network according to claim 23, wherein said second interface is configured to switch off said second transmitter if the light level increases above said predetermined threshold value.

25. The protected single-fiber passive optical network according to claim 23, wherein said second interface is configured to keep said second transmitter switched on if the light level increases above said predetermined threshold value.

26. The protected single-fiber passive optical network according to claim 25, wherein said second interface is configured to switch said second transmitter off and again on in order to verify that the cable is still broken.

27. The protected single-fiber passive optical network according to claim 23, wherein said second interface is configured to switch off said second transmitter if detecting with said detector abrupt

changes in the amount of light after switching on said second transmitter.

28. The protected single-fiber passive optical network according to claim 27, wherein said second interface is configured to switch on said second transmitter again if the light level decreases below said predetermined threshold value.

29. The protected single-fiber passive optical network according to claim 22, wherein if said first and second interfaces are located in a single optical line terminal, said second interface comprises:

starting means for starting an auto-discovery process to register affected optical network units; and

updating means for updating an internal routing table of said optical line terminal in response to the result of said auto-discovery process.

30. The protected single-fiber passive optical network according to claim 22, wherein if said first and second interfaces are located in different optical line terminals:

said second interface comprises starting means for starting an auto-discovery process to register affected optical network units;

said second interface comprises establishing means for establishing a dedicated path between said interfaces;

said second interface comprises sending means for sending a notifying message to said first interface, said notifying message comprising information about said affected optical network units;

said first interface comprises forwarding means for forwarding the downstream traffic of said affected optical network units to said second interface via said dedicated path; and

said second interface comprises forwarding means for forwarding the affected upstream traffic from said affected optical network units to said first interface via said dedicated path.

31. The protected single-fiber passive optical network according to claim 29, wherein said first interface further comprises:

sending means for sending to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

32. The protected single-fiber passive optical network according to claim 31, wherein said second interface comprises:

checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending means for sending said packet according to said routing table, and if said destination address is not found in said routing table, said sending means configured to send said packet from said second interface to said first interface via said dedicated path.

33. A protected single-fiber passive optical network comprising:

a first interface comprising a first transmitter and a first receiver;

a second interface comprising a second transmitter and a second receiver;

an optical fiber connection between said interfaces;

a plurality of passive nodes between said interfaces;

a plurality of optical network units connected to said plurality of passive nodes;

detecting means for detecting in said first interface that signals are not received from at least one optical network unit; and sending means for sending to said second interface a message to switch on said transmitter of said second interface.

34. The protected single-fiber passive optical network according to claim 33, wherein:

said second interface is configured to switch off said transmitter of said second interface if said first interface detects that the number of optical network units from which signals are not received increases.

35. The protected single-fiber passive optical network according to claim 33, wherein if said first and second interfaces are located in a single optical line terminal, said second interface comprises:

starting means for starting an auto-discovery process to register affected optical network units; and

updating means for updating an internal routing table of said optical line terminal in response to the result of said auto-discovery process.

36. The protected single-fiber passive optical network according to claim 33, wherein if said first and second interfaces are located in different optical line terminals:

said first interface comprises establishing means for establishing a dedicated path between said interfaces;

said second interface comprises starting means for starting an auto-discovery process to register affected optical network units;

said second interface comprises sending means for sending a notifying message to said first interface, said notifying message comprising information about said affected optical network units;

said first interface comprises forwarding means for forwarding the downstream traffic of said affected optical network units to said second interface via said dedicated path; and

said second interface comprises forwarding means for forwarding the affected upstream traffic from said affected optical network units to said first interface via said dedicated path.

37. The protected single-fiber passive optical network according to claim 36, wherein said first interface further comprises:

sending means for sending to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

38. The protected single-fiber passive optical network according to claim 37, wherein said second interface comprises:

checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending means for sending said packet according to said routing table, and if said destination address is not found in said routing table, said sending means configured to send said packet from said second interface to said first interface via said dedicated path.

39. An interface arrangement for a protected single-fiber passive optical network, the arrangement comprising:

a first interface comprising a first transmitter coupled to said fiber for transmitting optical signals on a first wavelength and a first receiver coupled to said fiber for receiving optical signals on a second wavelength;

a second interface comprising a second transmitter coupled to said fiber for transmitting optical signals on a second wavelength and a second receiver coupled to said fiber for receiving optical signals on a first wavelength;

detecting means for detecting that signals are not received from at least one optical network unit; and

sending means for sending to said second interface a message to switch on said second transmitter of said second interface.

40. The interface arrangement according to claim 39, wherein:

said second interface is configured to switch off said transmitter of said second interface if said first interface detects that the number of optical network units from which signals are not received increases.

41. The interface arrangement according to claim 39, wherein if said first and second interfaces are located in a single optical line terminal, said second interface comprises:

starting means for starting an auto-discovery process to register affected optical network units; and

updating means for updating an internal routing table of said optical line terminal in response to the result of said auto-discovery process.

42. The interface arrangement according to claim 39, wherein if said first and second interfaces are located in different optical line terminals:

said first interface comprises establishing means for establishing a dedicated path between said interfaces;

said second interface comprises starting means for starting an auto-discovery process to register affected optical network units;

said second interface comprises sending means for sending a notifying message to said first interface, said notifying message comprising information about said affected optical network units;

said first interface comprises forwarding means for forwarding the downstream traffic of said affected optical network units to said second interface via said dedicated path; and

said second interface comprises forwarding means for forwarding the affected upstream traffic from said affected optical network units to said first interface via said dedicated path.

43. The interface arrangement according to claim 42, wherein said first interface further comprises:

sending means for sending to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

44. The interface arrangement according to claim 43, wherein said second interface comprises:

checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending means for sending said packet according to said routing table, and if said destination address is not found in said routing table, said sending means configured to send said packet from said second interface to said first interface via said dedicated path.

45. An interface arrangement for a protected single-fiber passive optical network, the interface arrangement comprising:

a first interface comprising a first transmitter coupled to said fiber for transmitting optical signals on a first wavelength and a first receiver coupled to said fiber for receiving optical signals on a second wavelength;

a second interface comprising a second transmitter coupled to said fiber for transmitting optical signals on a second wavelength and a second receiver coupled to said fiber for receiving optical signals on a first wavelength;

a detector coupled to said fiber for detecting the degradation in power level of incoming optical signals of said first wavelength via said fiber; and in response to detecting, said second interface is configured to switch on said second transmitter in response to detecting said degradation in power level of said optical signals of said first wavelength via said fiber.

46. The interface arrangement according to claim 45, wherein said second interface is configured to switch on said second transmitter when the optical power of the received optical signals of said first wavelength via said fiber drops below a predetermined threshold value.

47. The interface arrangement according to claim 46, wherein said second interface is configured to switch off said second transmitter if the light level increases above said predetermined threshold value.

48. The interface arrangement according to claim 46, wherein said second interface is configured to keeping said second transmitter switched on if the light level increases above said predetermined threshold value.

49. The interface arrangement according to claim 48, wherein said second interface is configured to switch said second transmitter off and again on in order to verify that the cable is still broken.

50. The interface arrangement according to claim 46, wherein said second interface is configured to switch off said second transmitter if said detector detects abrupt changes in the amount of light after switching on said transmitter.

51. The interface arrangement according to claim 50, wherein said second interface is configured

to switch said second transmitter again on if the light level decreases below said predetermined threshold value.

52. The interface arrangement according to claim 45, wherein if said first and second interfaces are located in a single optical line terminal, said second interface comprises:

starting means for starting an auto-discovery process to register affected optical network units; and

updating means for updating an internal routing table of said optical line terminal in response to the result of said auto-discovery process.

53. The interface arrangement according to claim 45, wherein if said first and second interfaces are located in different optical line terminals:

said second interface comprises starting means for starting an auto-discovery process to register affected optical network units;

said second interface comprises establishing means for establishing a dedicated path between said interfaces;

said second interface comprises sending means for sending a notifying message to said first interface, said notifying message comprising information about said affected optical network units;

said first interface comprises forwarding means for forwarding the downstream traffic of said affected optical network units to said second interface via said dedicated path; and

said second interface comprises forwarding means for forwarding the affected upstream traffic from said affected optical network units to said first interface via said dedicated path.

54. The interface arrangement according to claim 53, wherein said first interface further comprises:

sending means for sending to said second interface via said dedicated path which higher layer addresses are behind said affected optical network units.

55. The interface arrangement according to claim 54, wherein said second interface comprises:

checking means for checking whether a packet's destination address is found in a routing table of an optical line terminal comprising said second interface, and if said destination address is found in said routing table,

sending means for sending said packet according to said routing table, and if said destination address is not found in said routing table, said sending means configured to send said packet from said second interface to said first interface via said dedicated path.

L4

ABSTRACT OF THE DISCLOSURE

The invention describes a solution for detecting and recovering from a failure in a protected single-fiber passive optical network. A detector is used to detect the degradation in power level of optical signals. Furthermore, the invention discloses a variable symmetric split ratio approach to improve the number of splits (e.g. the number of ONUs). Moreover, the invention describes a single-fiber passive optical network using a plurality of passive nodes connected in the optical fiber between the interfaces, wherein in the passive nodes 2-by-2 splitters/combiners are used to couple optical power from and into the optical fiber at a predetermined split ratio.

15

1

PRIOR ART

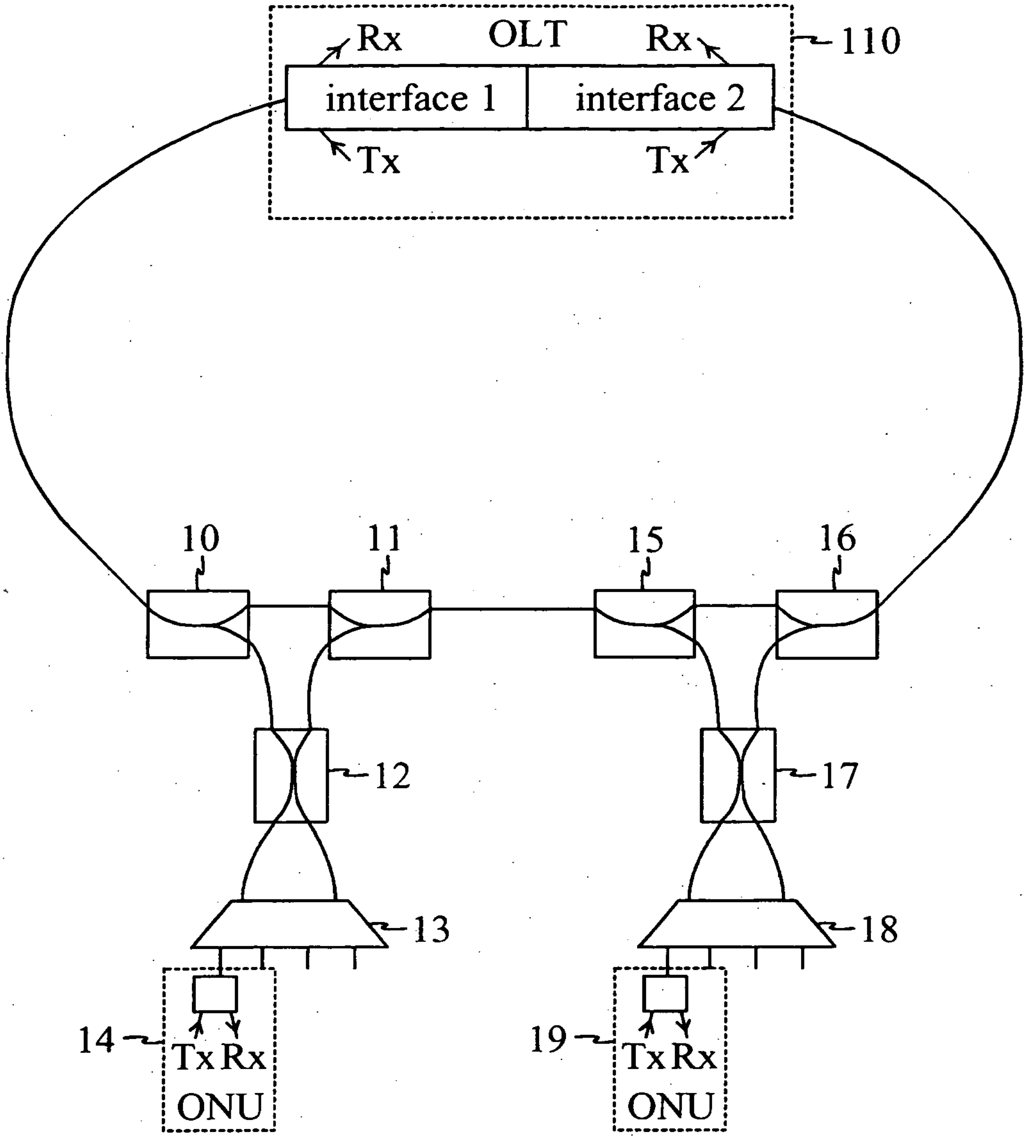

Fig. 1

25·07·03 031104

LS

2

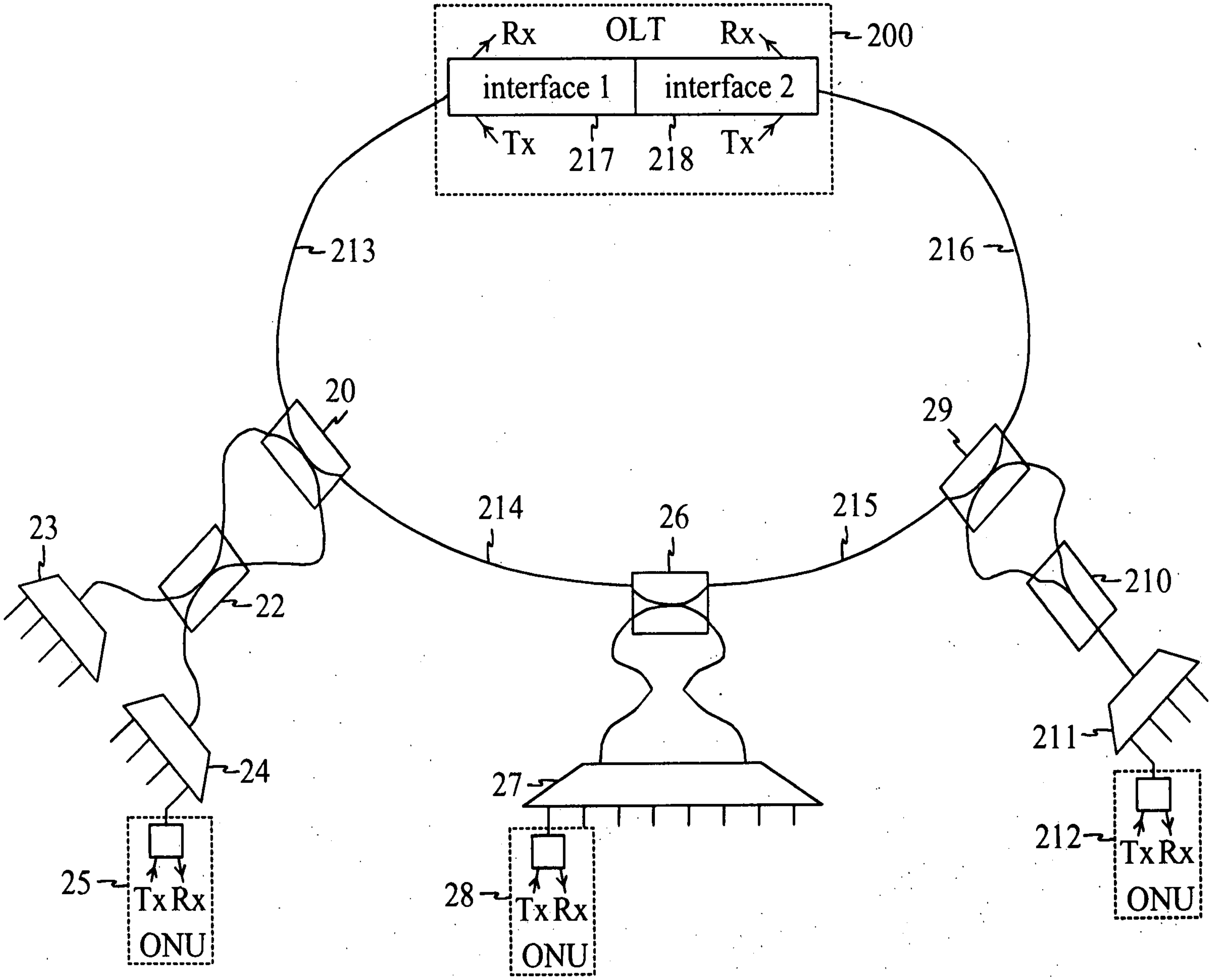

Fig. 2

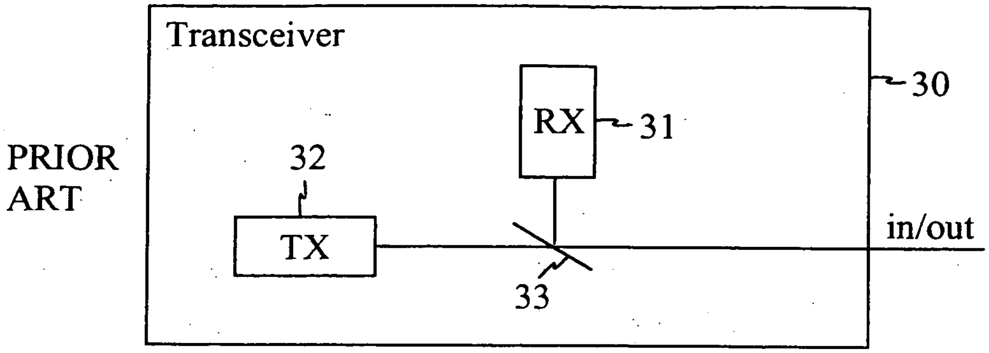

Fig. 3

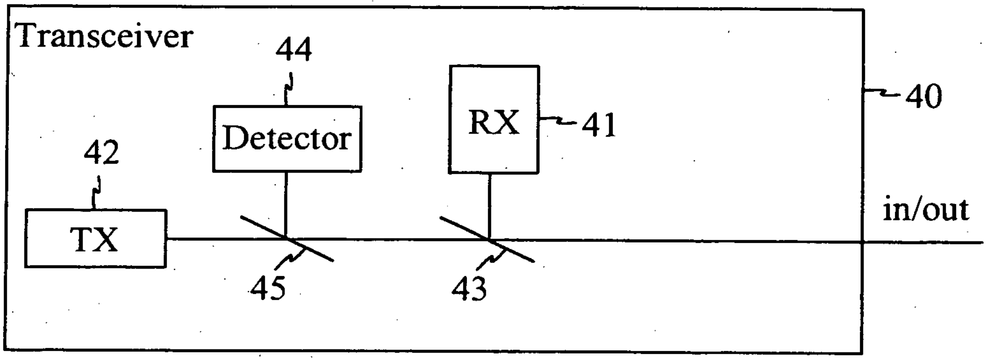

Fig. 4

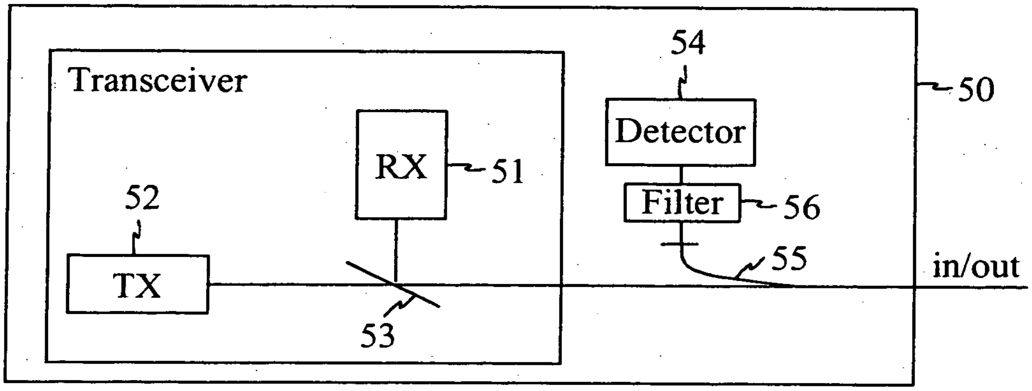

Fig. 5

15 4

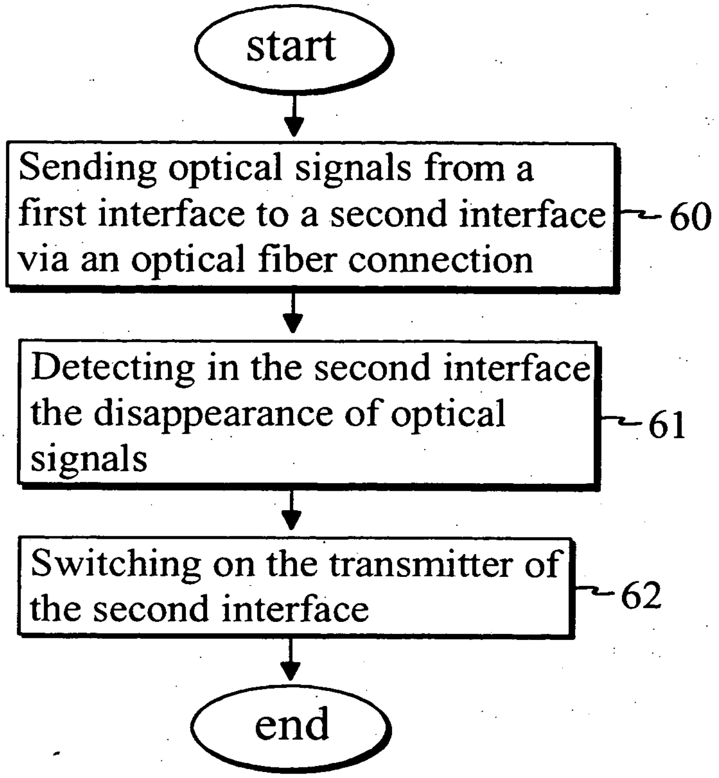
start
Sending optical signals from a first interface to a second interface via an optical fiber connection
60
Detecting in the second interface the disappearance of optical signals
61
Switching on the transmitter of the second interface
62
end

Fig. 6

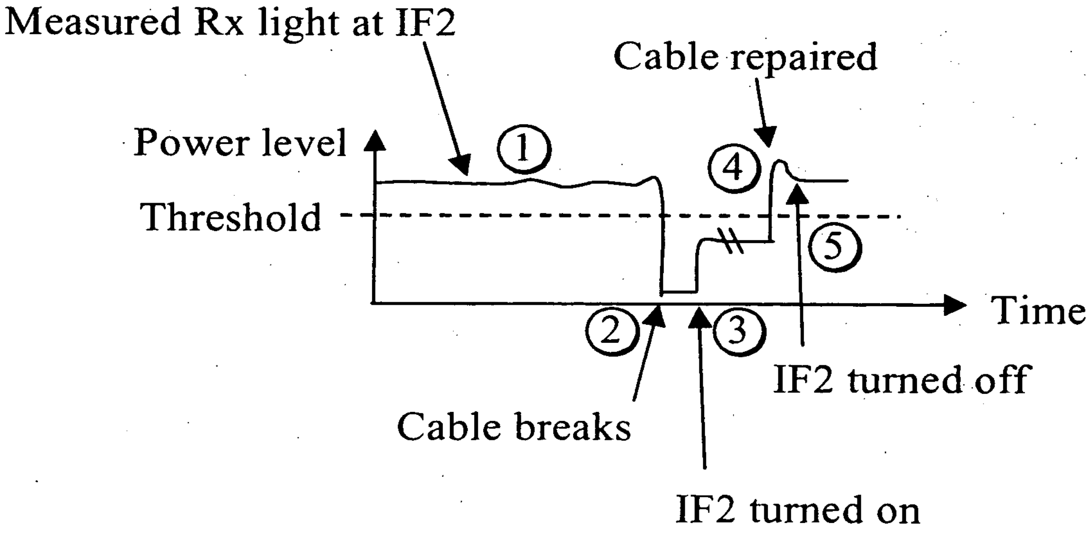

Fig. 7

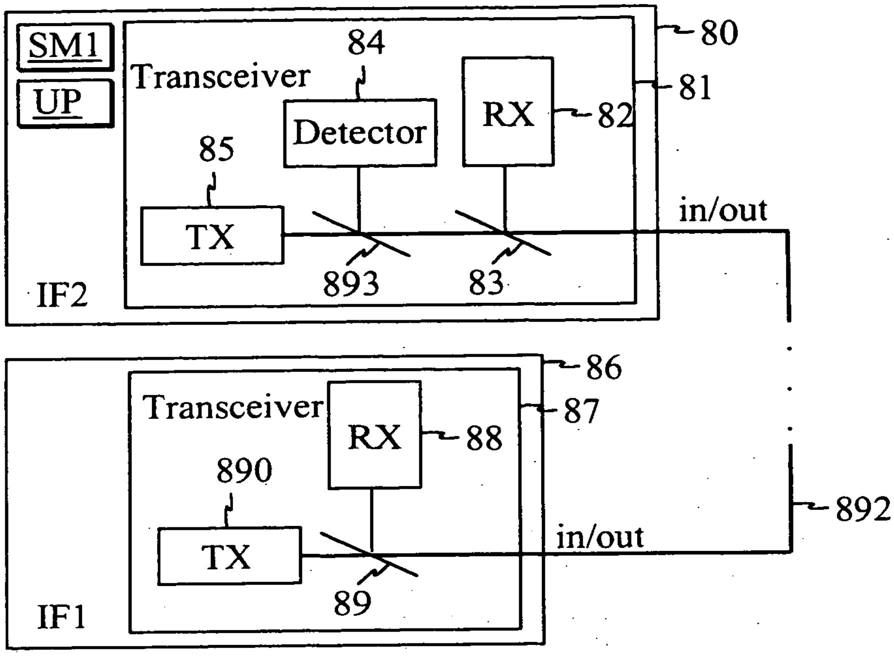
SM1
UP
Transceiver
84
Detector
RX
82
85
TX
893
83
in/out
IF2
80
81
86
87
Transceiver
RX
88
890
TX
89
in/out
IF1
892

Fig. 8a

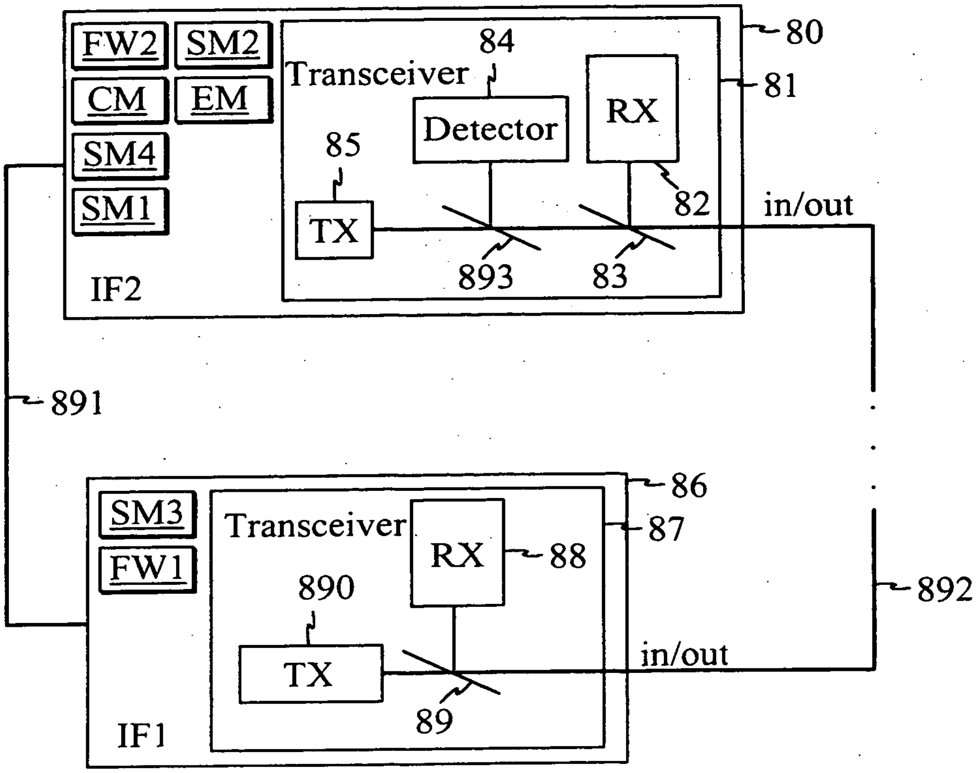
FW2
SM2
CM
EM
SM4
SM1
Transceiver
84
Detector
RX
85
TX
82
893
83
in/out
IF2
80
81
891
SM3
FW1
Transceiver
RX
88
890
TX
89
in/out
IF1
86
87
892

Fig. 8b

15 6

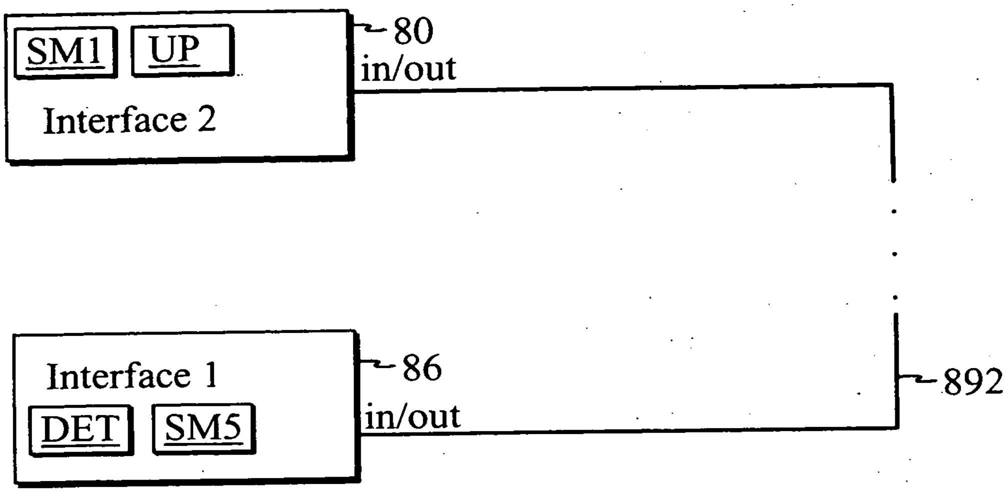

Fig. 8c

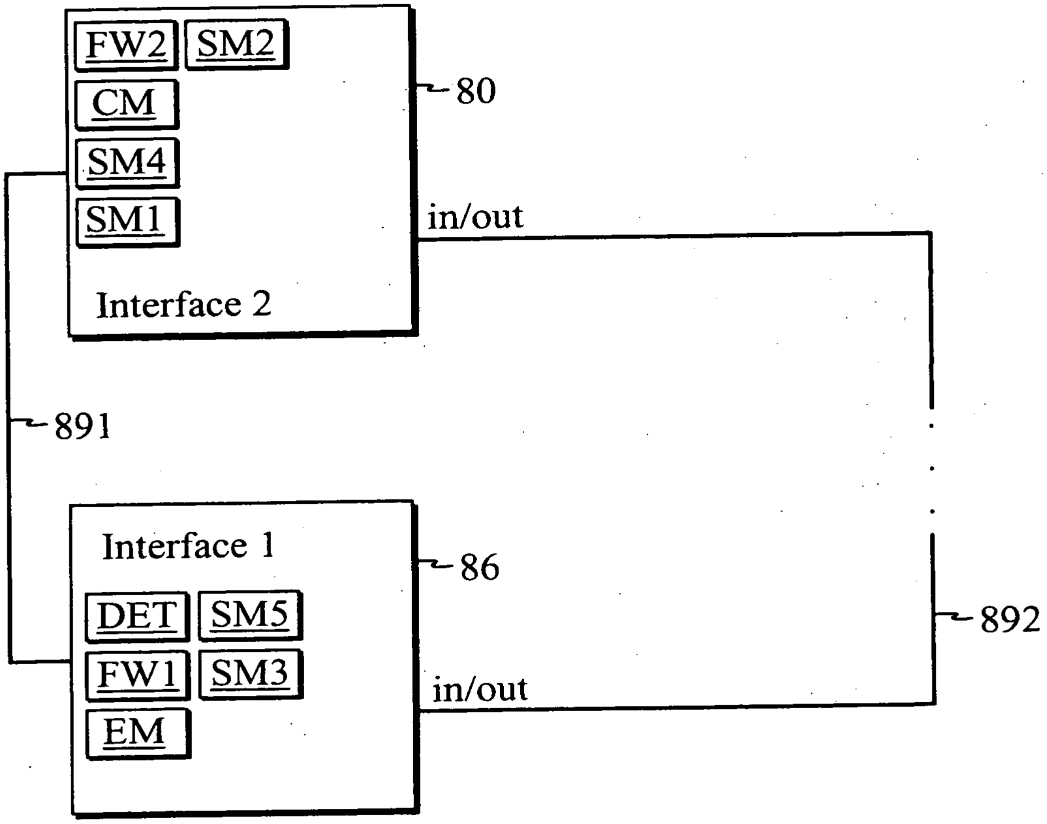

Fig. 8d

L5

7

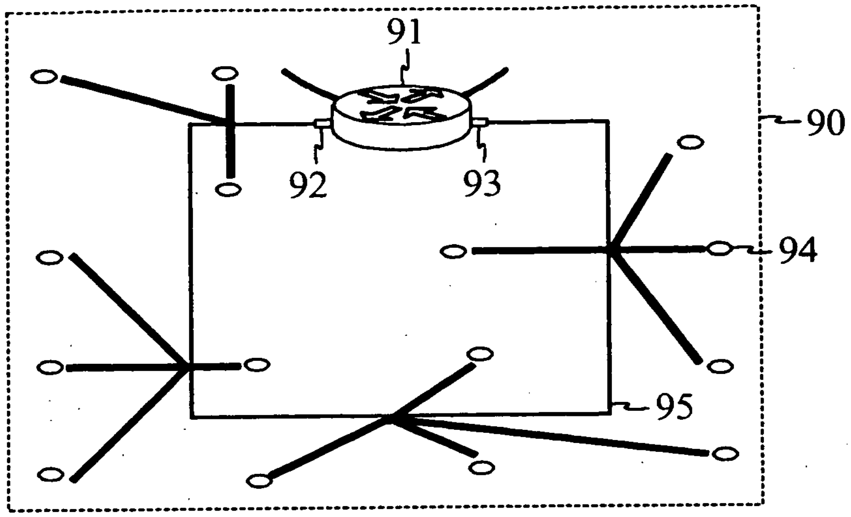

Fig. 9

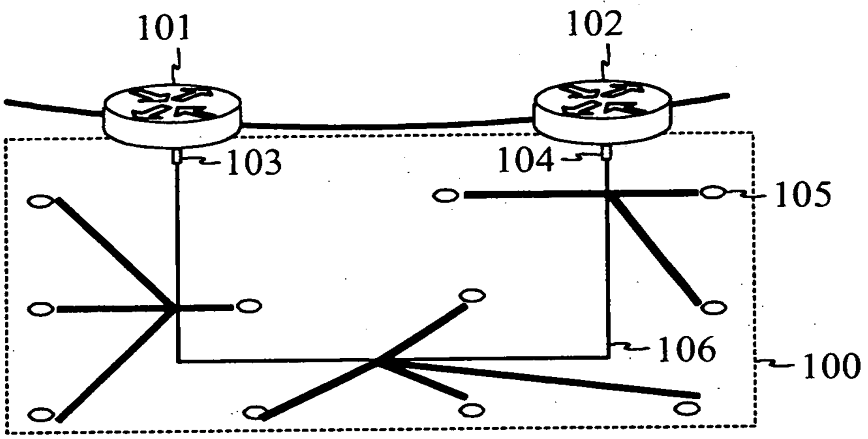

Fig. 10

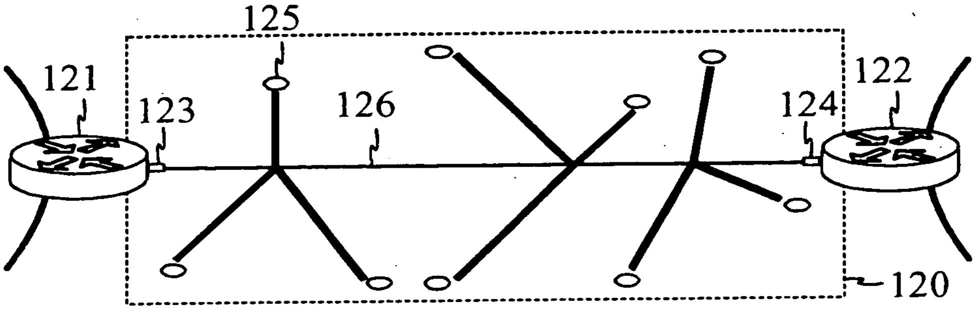

Fig. 11

15

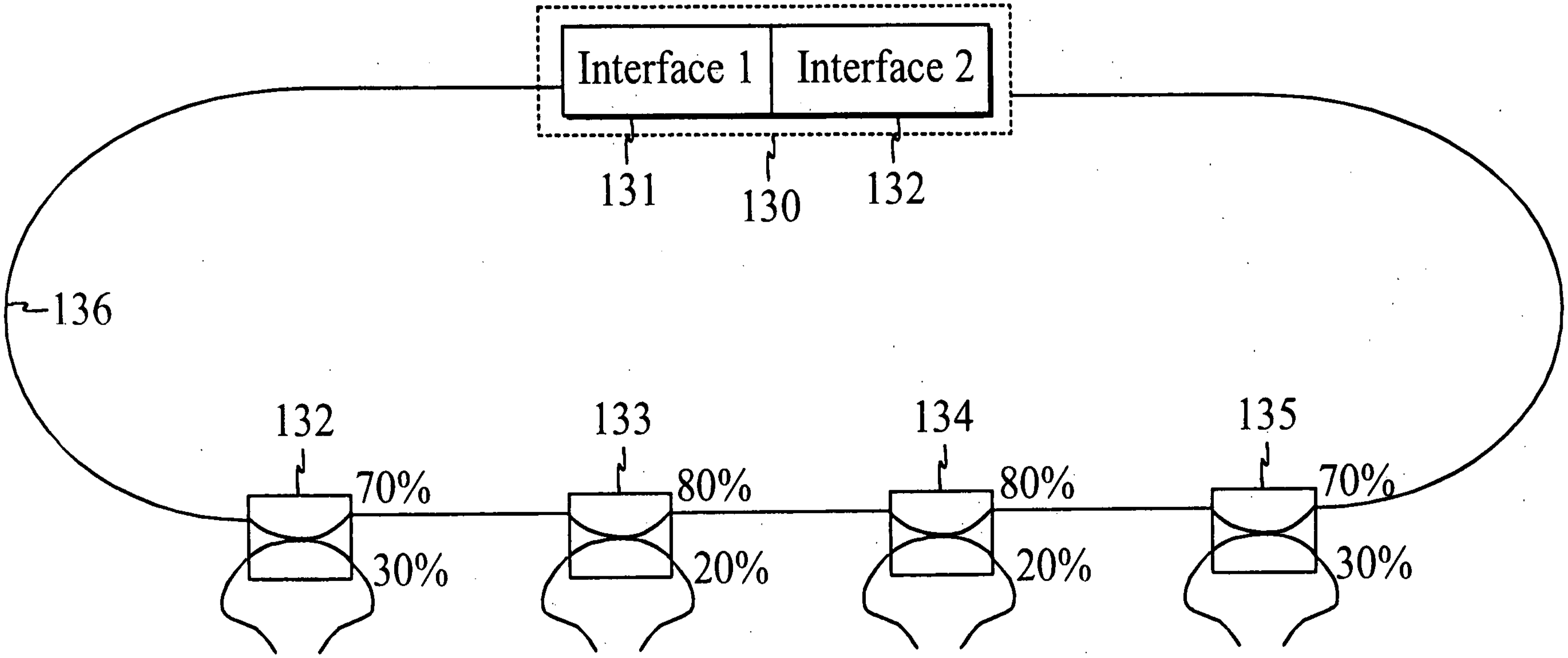
Interface 1
Interface 2
131
130
132
136
132
133
134
135
70%
30%
80%
20%
80%
20%
70%
30%

Fig. 12

8